2005

Factors Affecting Regional Variation in Growth of Channel Catfish

Bart W. Durham
Texas Tech University, bart.durham@ttu.edu

Kevin L. Pope
University of Nebraska-Lincoln, kpope2@unl.edu

Gene R. Wilde
Texas Tech University, gene.wilde@ttu.edu

Published in *North American Journal of Fisheries Management* 25 (2005), pp. 93-97; doi: 10.1577/M03-129.1

Submitted July 10, 2003; accepted July 26, 2004; published online February 28, 2005.

Factors Affecting Regional Variation in Growth of Channel Catfish

Bart W. Durham, Kevin L. Pope, and Gene R. Wilde

Wildlife and Fisheries Management Institute,
Mail Stop 2125, Texas Tech University, Lubbock, Texas 79409, USA

Corresponding author – Bart W. Durham, email bart.durham@ttu.edu

Abstract

We related the length at age of channel catfish Ictalurus punctatus, an indirect measure of growth, to three climatic and five morphoedaphic variables in 144 Texas reservoirs. Growth of channel catfish ages 3 through 6 was negatively related to longitude, a factor that explained as much as 34% of the variation in length at age. Channel catfish length at age was not significantly related to latitude, conductivity, morphoedaphic index, mean depth, and maximum depth in all age-classes. Among age-7 channel catfish, length at age was positively related to reservoir area, which explained 35% of the variation in growth. A quadratic model for growing-season length explained 7–17% of the variation in length at age in all age-classes. Overall, length at age for channel catfish was greatest in reservoirs with intermediate growing seasons (approximately 270 d in length) and was lower when the growing-season length was either longer or shorter. Our results provide the first evidence that the length of growing season on a statewide or regional scale may affect the growth of channel catfish.

Native or introduced populations of channel catfish *Ictalurus punctatus* are present in almost all of the 50 states in the USA (Miller 1966). Nationwide, channel catfish is one of the most frequently targeted freshwater fishes (U.S. Fish and Wildlife Service and Bureau of the Census 2002); consequently, managers in most states recognize the need to actively manage channel catfish fisheries (Vanderford 1984). Despite the popularity of channel catfish among recreational anglers, most studies of the species have been directed towards aquaculture. As a result, factors that influence the population dynamics of wild channel catfish populations targeted by anglers remain unknown. In a recent literature review, Hubert (1999) identified the need for more studies on the factors affecting the growth of channel catfish. Although growth of the species varies substantially across its range, it has never been related to regional variation in climatic factors such as temperature or growing-season length (Hubert 1999). In this study, we sought to determine if growth of age-1 through age-7 channel catfish in 144 Texas reservoirs was related to three climatic and five morphoedaphic variables.

Methods

Channel catfish were collected during routine spring (January through May) gill-net sampling from 176 Texas reservoirs between 1975 and 1995. Pectoral spines were collected from a subsample of fish from each reservoir for use in age and growth analyses. Spines were collected haphazardly from up to five individual fish per inch-group. Because samples only occasionally contained more than five fish per inch-group, the ages of most collected fish were estimated. In preparation for age estimation, pectoral spines were sectioned distal to the articulating process and mounted on glass slides (DeVries and Frie 1996). This sectioning technique has been shown to reduce age estimation error of older catfish specimens (Nash and Irwin 1999). Mean total length at age for channel catfish from each reservoir was calculated. We retained for analyses only those reservoir–age-group combinations for which a minimum of five age estimates was available following Pope et al. (2004) and Wilde and Muoneke (2001). This resulted in a final sample of 595 channel catfish aged 1 to 7 years from 144 reservoirs located throughout Texas.

We used correlation analyses and linear and quadratic regression to examine the nature and strength of the relationship between mean length at age and three climate-related and five morphoedaphic variables. Climate-related variables included latitude, longitude, and length of growing season (defined as number of frost-free days per year). Morphoedaphic variables included conductiv-

Table 1. Minima (Min) and maxima (Max) for three climatic and five morphoedaphic variables, number of reser voirs (*n*), and correlation coefficients (*r*) relating channel catfish length at age 1 through age 7 and climatic and morphoedaphic variables in Texas reservoirs. Conductivity and the morphoedaphic index (MEI) were $\log_{10}$ transformed. Correlation coefficients for growing-season length are based on quadratic models. Asterisks indicate significant corre lations based on the sequential Bonferroni test ($P \leq 0.05$)

			Age 1		Age 2		Age 3		Age 4	
Variable	Min	Max	*n*	*r*	*n*	*r*	*n*	*r*	*n*	*r*
Latitude (°N)	25.9	35.8	57	0.21	111	0.08	121	0.02	110	–0.06
Longitude (°W)	93.6	103.7	57	–0.04	111	–0.24	121	–0.05*	110	–0.39*
Growing season (d)	187.0	341.0	57	0.17	111	0.26*	121	0.33*	110	0.36*
Conductivity (μS/cm)	1.8	3.7	55	0.17	107	0.08	116	0.28	107	0.36
MEI	1.3	3.8	53	–0.09	104	0.08	110	–0.10	102	–0.02
Mean depth (m)	0.3	16.0	55	0.22	107	0.00	114	0.02	104	0.09
Maximum depth (m)	0.9	61.0	57	0.27	108	0.03	115	0.04	106	0.14
Area (ha)	0.4	74925.0	57	0.11	111	–0.13	121	–0.13	110	0.06

ity, Ryder's (1965) morphoedaphic index (MEI), mean and maximum depth, and reservoir surface area. Inspection of scatterplots of growth versus each independent variable indicated linear relationships for all variables except for conductivity and MEI, for which logarithmic transformations were used, and growing-season length, for which a quadratic relationship was most appropriate (Miranda and Durocher 1986; Wilde and Muoneke 2001; Pope et al. 2004). In all cases, there was no evident departure from normality among residuals. Length of growing season was obtained from Ramos (1995). Information for all other variables was obtained from Texas Parks and Wildlife Department's Lake Categorization File, a database of water quality and morphometric data for Texas reservoirs. To control the probability of falsely rejecting null hypotheses, we used the sequential Bonferroni test with a table-wide significance of 0.05 to evaluate test statistics (Rice 1989). Regardless of statistical significance of individual correlations, two-tailed binomial tests (Siegel 1956) were used to determine whether there was an excess proportion of positive or negative correlations between length at each age and climatic and morphoedaphic variables. Under the null hypothesis of no correlation, we expected 50% of the correlations to be positive and 50% to be negative for each age-class. Exact *P*-values for the binomial test can be calculated by expanding the binomial probability function, or for small (<25) sample sizes, *P*-values are presented in tables in Siegel (1956). All statistical analyses were performed with SAS software (SAS Institute, Cary, North Carolina).

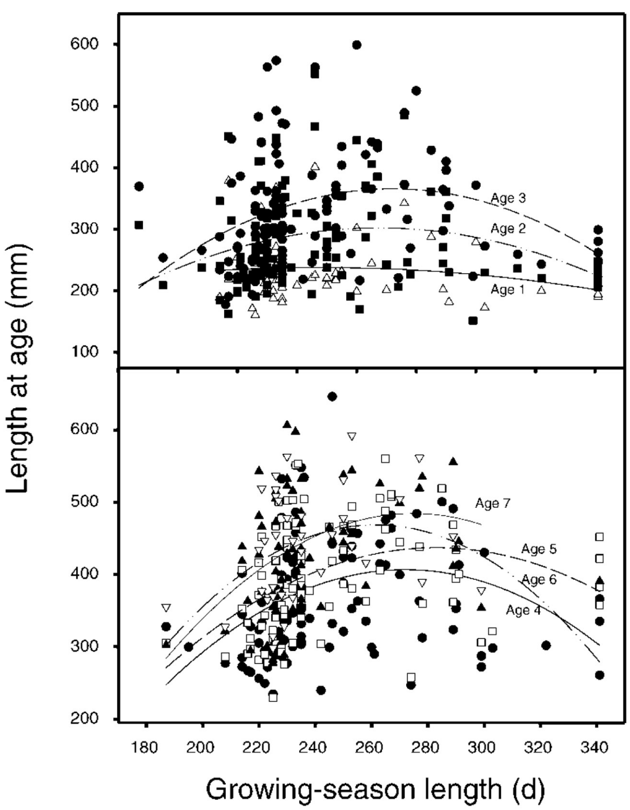

Figure 1. Relationships between mean length at age and growing-season length for 144 Texas channel catfish populations. Symbols represent the means of five or more observations for each reservoir and are defined as follows: open upright triangles = age-1 fish; solid squares = age-2 fish; circles = age-3 and age-4 fish; open squares = age-5 fish; solid upright triangles = age-6 fish; and open inverted triangles = age-7 fish.

Results

Across all study reservoirs, mean ± SE total lengths at capture (and ranges) of channel catfish were as follows: age 1, 234 ± 6.9 mm (161–401 mm; *N* = 57) ; age 2, 277 ± 7.1 mm (152–552 mm; *N* = 111); age 3, 327 ± 8.0 mm (178–599 mm; *N* = 121); age 4, 365 ± 7.5 mm (234–646 mm; *N* = 110); age 5, 396 ± 7.9 mm (229–560 mm; *N* = 96); age 6, 430 ± 10.5 mm (277–606 mm; *N* = 62); and age 7, 437 ± 12.2 mm (298– 592 mm; *N* = 38). Length at age among

Table 1. — Extended.

	Age 5		Age 6		Age 7	
	n	*r*	*n*	*r*	*n*	*r*
Latitude (°N)	95	20.15	62	20.10	38	20.16
Longitude (°W)	96	20.49*	62	20.51*	38	20.59
Growing season (d)	96	0.37*	62	0.41*	38	0.39
Conductivity (μS/cm)	92	20.02	62	0.23	38	0.46
MEI	87	0.14	60	0.06	37	0.20
Mean depth (m)	90	0.16	60	0.06	37	0.01
Maximum depth (m)	93	0.17	62	0.12	38	0.41
Area (ha)	96	0.04	62	0.05	38	0.59*

age-3 (r =−0.35; N = 121; P = 0.0001), age-4 (r =−0.39; N = 110; P = 0.0001), age-5 (r =−0.49; N = 96; P = 0.0001), and age-6 (r =−0.51; N = 62; P = 0.0001) channel catfish was significantly negatively correlated with longitude and explained 13– 34% of the variation in length at age (Table 1). Length at age among age-1 and age-2 (r =−0.24 to−0.04; N = 57–121; P = 0.10–0.76) channel catfish was not significantly correlated with longitude. Length of age-7 channel catfish was positively correlated (r = 0.59; N = 38; P = 0.0001) with reservoir area, which explained 35% of the variation (Table 1). For each channel catfish age-group, after Bonferroni adjustment, length at age was not significantly related to latitude, growing season, conductivity, MEI, mean depth, or maximum depth (r =−0.16 to +0.46; P > 0.05).

A quadratic model for growing-season length was significantly correlated with length at age among age-2 (F = 7.67; df = 2, 108; P = 0.0066), age-3 (F = 14.20; df = 2, 118; P = 0.0003), age-4 (F = 14.32; df = 2, 107; P = 0.0003), age-5 (F = 10.17; df = 2, 93; P = 0.0019), and age-6 (F = 8.15; df = 2, 59; P = 0.0066) channel catfish and explained 7–17% of the variation in length at age (Table 1). For all age-groups, the relationship between channel catfish length at age and growing-season length was dome shaped (Figure 1). Length at age was greatest in reservoirs with a growing-season length of about 270 d and decreased in reservoirs with shorter or longer growing seasons. This pattern was consistent across all age-groups. Populations distinguished by slow growth rates for age-1 fish continued to grow slowly and failed to reach the statewide average length in subsequent years.

Channel catfish growth generally decreased with longitude and MEI and generally increased with mean and maximum depth. For all ages, regardless of the significance of individual correlations, an excess proportion of correlations between growth and mean depth and maximum depth were positive (P = 0.016), and an excess proportion of correlations between growth and longitude were negative (P = 0.016). There was no significant (P > 0.124) excess in the proportion of positive (or negative) correlations between length at age and latitude, growing-season length, conductivity, and reservoir area.

Discussion

Our results provide the first evidence that length of growing season may affect the growth of channel catfish on statewide or regional scales. Climatic factors are known to influence growth and yield of fish species with broad geographic distributions. However, the degree to which climatic factors affect fish growth at regional and local scales is not well documented (Schlesinger and Regier 1982). Carlander (1969) observed that faster growing channel catfish populations typically occurred in the southern portion of the species range, but he concluded that more comprehensive evidence was needed to determine if regional differences in growth commonly occur. Growing-season length has been shown to be a significant predictor of growth in both white bass *Morone chrysops* (Wilde and Muoneke 2001) and white crappie *Pomoxis annularis* (Pope et al. 2004) in Texas. However, Miranda and Durocher (1986) found no significant relationship between growingseason length and growth of largemouth bass *Micropterus salmoides* in Texas. Thus, it appears there is no general relationship across species between growing-season length and growth.

Growing-season length differs by as much as 160 d among Texas reservoirs (Ramos 1995). We found growth of channel catfish was greatest in reservoirs with intermediate growing-season lengths (about 270 d). Growth of channel catfish also was negatively related to longitude. In Texas, elevation increases and precipitation decreases from southeast to northwest (Miranda and Durocher 1986; Ground and Groeger 1994; Wilde and Muoneke 2001), possibly explaining the longitudinal relationship with growth. Relationships between growth and growing season and longitude suggest that channel catfish growth may be affected by several environmental gradients across the state; however, growing-season length appears to have the greatest effect on channel catfish growth. Growth of channel catfish in north Texas reservoirs is likely reduced because these populations experience the shortest growing seasons, whereas in southern reservoirs, growth is presumably reduced because summer water temperatures exceed the optimum (30–32°C) for growth of channel catfish (Kilambi et al. 1971; Andrews and Stickney 1972). High water temperature also may affect growth by causing channel catfish to stop feeding as it does in other species such as striped bass *Morone saxatilis* (e.g., Lochmiller et al. 1989; Zale et al. 1990), or by increasing metabolic demands to a level not compensated for by increased food consumption as in white crappie (e.g., Hayward and Arnold 1996).

Growth of channel catfish was weakly associated with mean and maximum depth, as evidenced by significant excesses of positive correlations. This result is contrary to the inverse relationship between fish production and depth that typically is observed in lakes and reservoirs (Rawson 1952; Ryder 1965; Carline 1986). It is possible that growth of channel catfish is unrelated to depth and productivity. Alternatively, the capture efficiency of gill nets used to sample channel catfish may vary among lakes differing in morphometric characteristics (e.g., Blackwell and Brown 2000), obscuring any relationship between growth and depth.

Our analyses consider only reservoir populations and provide no direct insight into geographic variation in the growth of riverine channel catfish populations. Although riverine populations are likely to grow at a different rate than lake and reservoir populations, there is no reason to anticipate any difference in the nature of the relationship between growth and growing-season length between these habitats. Additional study of riverine populations is needed to clarify growth patterns at a regional scale in lotic systems.

Several life history characteristics of channel catfish (including maturity, fecundity, and mortality) are related to length (Appleget and Smith 1951; Jearld and Brown 1971; Hubert 1999). Therefore, geographic variation in growth may affect local population dynamics and the length of time needed for channel catfish to reach harvestable size (Miranda and Durocher 1986). Ignoring geographic patterns in growth (and hence population dynamics) may simplify fishery management but may result in angler dissatisfaction in areas with extremely long or short growing-season lengths. In such cases, regional or water body-specific management practices and regulations may be preferable to management with statewide regulations.

Acknowledgments - We thank Texas Parks and Wildlife Department Inland Fisheries personnel for collection of the data reported in this paper. Chris Chizinski and Todd Byerly commented on earlier drafts of this manuscript. This is contribution number T-9–1010 of the College of Agricultural Sciences and Natural Resources, Texas Tech University.

References

Andrews, J. W. and Stickney, R. R. 1972. Interactions of feeding rates and environmental temperature on growth, food conversion, and body composition of channel catfish. *Transactions of the American Fisheries Society*, 101: 94–99.

Appleget, J. and Smith, L. L. Jr. 1951. The determination of age and rate of growth from vertebrae of the channel catfish, Ictalurus lacustris punctatus. *Transactions of the American Fisheries Society*, 80: 119–139.

Blackwell, B. G. and Brown, M. L. 2000. A comparison of fish distributions in simple and complex lake basins. *Journal of Freshwater Ecology*, 15: 353–362.

Carlander, K. D. 1969. *Handbook of freshwater fishery biology* Ames: Iowa State University Press.

Carline, R. F. 1986. “Indices as predictors of fish community traits”. In *Reservoir fisheries management: strategies for the 80’s* Edited by: Hall, G. E. and Van Den Avyle, M. J. 46–56. Southern Division, Reservoir Committee, Bethesda, Maryland: American Fisheries Society.

DeVries, D. R. and Frie, R. V. 1996. “Determination of age and growth”. In *Fisheries techniques,* , 2nd edition Edited by: Murphy, B. R. and Willis, D. W. 483–512. Bethesda, Maryland: American Fisheries Society.

Ground, T. A. and Groeger, A. W. 1994. Chemical classification and trophic characteristics of Texas reservoirs. *Lake and Reservoir Management*, 10: 189–201.

Hayward, R. S. and Arnold, E. 1996. Temperature dependence of maximum daily consumption in white crappie: implications for fisheries management. *Transactions of the American Fisheries Society*, 125: 132–138.

Hubert, W. A. Biology and management of channel catfish. Catfish 2000: proceedings of the first international ictalurid symposium. Edited by: Irwin, E. R., Hubert, W. A., Rabeni, C. F., Schramm, H. L. Jr. and Coon, T. pp.3–22. Bethesda, Maryland: American Fisheries Society. Symposium 24

Jearld, A. Jr. and Brown, B. E. 1971. Fecundity, age and growth, and condition of channel catfish in an Oklahoma reservoir. *Proceedings of the Oklahoma Academy of Science*, 51: 15–22.

Kilambi, R. V., Noble, J. and Hoffman, C. E. 1971. Influence of temperature and photoperiod on growth, food consumption, and food conversion efficiency of channel catfish. *Proceedings of the Annual Conference Southeastern Association of Game and Fish Commissioners*, 24(1970): 519–531.

Lochmiller, R. L., Wiechman, J. D. and Zale, A. V. 1989. Hematological assessment of temperature and oxygen stress in a reservoir population of striped bass (Morone saxatilis). *Comparative Biochemistry and Physiology A*, 93: 535–541.

Miller, E. E. 1966. "Channel catfish". In *Inland fisheries management* Edited by: Calhoun, A. 440–463. Sacramento: California Department of Fish and Game.

Miranda, L. E. and Durocher, P. P. 1986. "Effects of environmental factors on growth of largemouth bass in Texas reservoirs". In *Reservoir fisheries management: strategies for the 80's* Edited by: Hall, G. E. and Van Den Avyle, M. J. 115–121. Southern Division, Reservoir Committee, Bethesda, Maryland: American Fisheries Society.

Nash, M. K. and Irwin, E. R. Use of otoliths versus pectoral spines for aging adult flathead catfish. Catfish 2000: proceedings of the first international ictalurid symposium. Edited by: Irwin, E. R., Hubert, W. A., Rabeni, C. F., Schramm, H. L. Jr. and Coon, T. pp.3–22. Bethesda, Maryland: American Fisheries Society. Symposium 24

Pope, K. L., Wilde, G. R. and Durham, B. W. 2004. Age-specific patterns in density-dependent growth of white crappie, Pomoxis annularis. *Fisheries Management and Ecology*, 11: 33–38.

Ramos, M. G. 1995. *The Texas almanac* Dallas, Texas: A. H. Belo Corporation.

Rawson, D. S. 1952. Mean depth and the fish production of large lakes. *Ecology*, 33: 513–521.

Rice, W. R. 1989. Analyzing tables of statistical tests. *Evolution*, 43: 223–225.

Ryder, R. A. 1965. A method for estimating the potential fish production of north-temperate lakes. *Transactions of the American Fisheries Society*, 94: 214–218.

Schlesinger, D. A. and Regier, H. A. 1982. Climatic and morphoedaphic indices of fish yields from natural lakes. *Transactions of the American Fisheries Society*, 111: 141–150.

Siegel, S. 1956. *Nonparametric statistics for the behavioral sciences* New York: McGraw-Hill.

U.S. Fish and Wildlife Service and Bureau of the Census. 2002. *2001 national survey of fishing, hunting, and wildlife-associated recreation* Washington, D.C.: U.S. Government Printing Office.

Vanderford, M. J. 1984. *Channel catfish management in the 50 states* St. Paul, Minnesota: U.S. Fish and Wildlife Service.

Wilde, G. R. and Muoneke, M. I. 2001. Climate-related and morphoedaphic correlates of growth in white bass. *Journal of Fish Biology*, 58: 453–461.

Zale, A. V., Wiechman, J. D., Lochmiller, R. L. and Burroughs, J. 1990. Limnological conditions associated with summer mortality of striped bass in Keystone Reservoir, Oklahoma. *Transactions of the American Fisheries Society*, 119: 72–76.